

MORPHOLOGY OF THE DIGESTIVE TRACT OF THE BLACKFLY (*SIMULIUM NIGROPARVUM*)¹

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INTRODUCTION

Comparatively little information exists in the literature relative to the internal anatomy of the family Simuliidae. Hungerford (6)² has figured and described the internal anatomy of *Simulium vittatum* Zett., and Smart (11) in a recent paper has described the internal anatomy of *S. ornatum* Mg.

In recent years it has been found that certain species of blackflies transmit disease-producing organisms. Blacklock (1, 2) has demonstrated that *simulium damnosum* Theob. is an intermediate host of a filarial worm *Onchocerca volvulus* Leuckart, which causes a disease of man. O'Roke (10) has shown that a blood protozoon of ducks, *Leucocytozoon anatis* Wickware, passes the sexual stage of its life cycle in *Simulium venustum* Say and that the organism is transmitted by the bite of the fly.

During the past 2 years the blackfly *Simulium nigroparvum* Twinn has been found feeding on turkeys in southwestern Virginia, and Johnson and Underhill (8) have shown that this fly is responsible for the transmission of a blood protozoon disease of turkeys. In view of the recent discovery that *S. nigroparvum* is an important vector of this blood protozoon of turkeys, the writer felt that a detailed study of the internal anatomy of the fly would be of service in studying the life history of the protozoon. Specimens of *S. nigroparvum* were readily accessible, and a detailed study was made of the internal morphology of this fly. Since only the females feed on turkeys and the males are unimportant as possible vectors, the digestive tract of the female only is described.

TECHNIQUE

Dissections were made on freshly killed specimens. For sectioning, the material was fixed in Bouin's fluid. All material was dehydrated with ethyl alcohol and cleared in terpineol. Hemalum and Delafield's haematoxylin were used for nuclear stains, and fast green and eosin for counter stains.

GROSS ANATOMY

The fore intestine (stomodaeum) is represented by the oesophagus and its diverticulum, the crop with its duct, and part of the cardiac valve. The mid intestine (mesenteron or ventriculus) is a simple tube, the anterior portion of which is narrow and the posterior portion

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² Italic numbers in parentheses refer to Literature Cited, p. 447.

of which is expanded and is capable of considerable distention. The hind intestine (proctodaeum) comprises the distal intestine, the Malpighian tubules, the rectal pouch and glands, and the rectum proper.

MOUTH PARTS AND SUCKING APPARATUS

The mouth parts of several species of blood-sucking Nematocera have been figured and described by several workers, among whom may be mentioned Dimmock (4), Kellogg (9), Emery (5), Cameron (3), Jobling (7), and Smart (11). The mouth parts of *Simulium nigroparvum* are the piercing, sucking type and are quite similar to those described by Cameron (3) for *S. simile* Mal. and by Smart (11) for *S. ornatum*. Observations made on living females of *S. nigroparvum* have demonstrated that the mode of biting is quite similar to that of *Culicoides pulicaris* L. as described by Jobling (7).

The mouth parts and biting apparatus are shown in plate 1. In general character the mouth parts are short and broad. The labrum-epipharynx (pl. 1, *F*) is a broad triangular structure which is kept rigid by three rodlike sclerotizations. At the tip of the labrum-epipharynx are two sclerotized trifid structures.

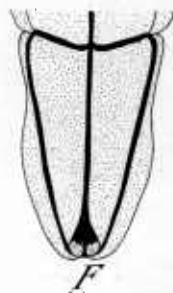
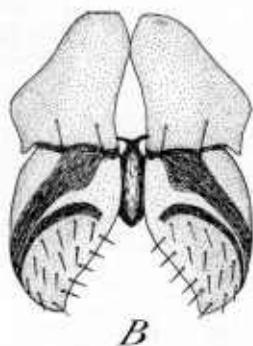
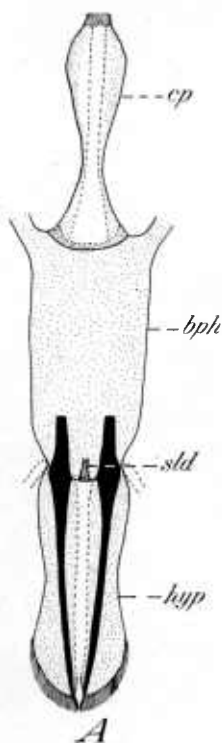
The hypopharynx (pl. 1, *A*) is a long narrow sclerotized rodlike structure the tip of which is armed with bristles. The salivary duct enters the proximal portion of the hypopharynx and is carried along the cephalic surface to the distal end.

The basipharynx is a flattened channel formed by the union of the hypopharynx and epipharynx. The labium (pl. 1, *B*) is short and broad and the theca appears to consist of two separate parts but actually they are fused at the base. The large, free labella curve round and forward, and when the insect is biting surround the other mouth parts. The proximal parts of the labella are rigidly sclerotized while the distal portions are soft and bear numerous setae on the surface.

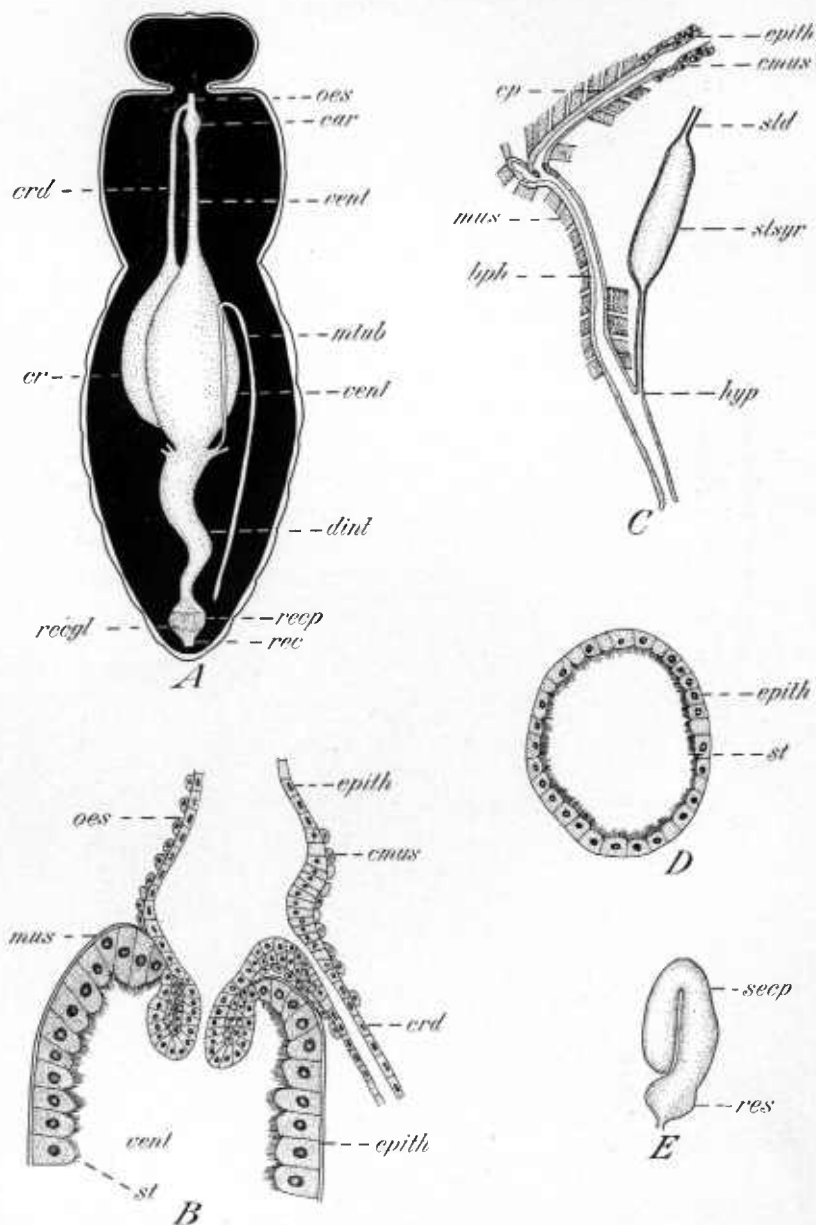
The maxillae lie along the outer margins of the labrum and hypopharynx. They are spear-shaped structures, the anterior face of which is flattened and is armed with teeth around its margin (pl. 1, *E*). The maxillary palps consist of five segments and are covered with numerous setae. The third segment bears a depressed saclike area which is probably a sensory vesicle (p. 1, *C*).

The mandibles are short, thin, swordlike structures fitted for piercing, and are armed with teeth on their anterior margins (pl. 1, *D*). Extending up the blade of each mandible from the marginal teeth are prominent striations. In the center of each mandible is a clear, crystallike area. The mandibles are so shaped that, for the greater part, the blades overlap between the labrum and the hypopharynx.

According to Snodgrass (12) the sucking apparatus of Diptera is the cibarium of orthopteroid insects and therefore would be called the cibarial pump. Also, the functional mouth aperture leading into the pump is actually not a true mouth. The true mouth occurs at the opening into the stomodaeum at the inner end of the pump. The cibarial pump of *Simulium nigroparvum* is triangular in section and consists of one dorsal sclerotized plate and two ventrolateral sclerotized plates. The pump is operated by muscles inserted on the plates (pl. 2, *C*).



Mouth parts of *Simulium nigroparvum*: A, Hypopharynx, basipharynx, and cibarial pump; B, labium; C, maxillary palp; D, mandible; E, maxilla; F, labrum epipharynx: *bph*, Basipharynx; *hyp*, hypopharynx; *cp*, cibarial pump; *sld*, salivary duct.



Simulium nigroparvum: A, diagrammatic dorsal view showing the alimentary canal and Malpighian tubules; B, longitudinal section through cardiac valve; C, sagittal section through basipharynx and cibarial pump; D, cross section through anterior portion of ventriculus; E, salivary gland. *bph*, Basipharynx; *cmus*, circular muscle; *crd*, crop duct; *cr*, crop; *dint*, distal intestine; *epith*, epithelium; *hyp*, hypopharynx; *mtub*, malpighian tubule; *mus*, muscle; *cp*, cibarial pump; *oes*, oesophagus; *car*, cardia; *rec*, rectum; *recpl*, rectal pouch; *recp*, rectal gland; *res*, reservoir; *secp*, Secretory part; *sld*, salivary duct; *stlsyr*, salivary syringe; *st*, striated margin of cell; *vent*, ventriculus.

SALIVARY GLANDS

The salivary glands, which are paired, lie in the anterior part of the thorax dorsad to the digestive tract. Each salivary gland is in the form of a U and is composed of two parts, viz, the anterior secretory part and the round saclike reservoir (pl. 2, *E*). A duct comes off from the reservoir of each gland. The two ducts from the salivary glands pass down, one on each side of the intestine, and unite beneath the oesophagus. The common duct leading from the point of junction expands to form the salivary syringe (pl. 2, *C*). From the salivary syringe the duct narrows and passes to the hypopharynx.

STOMODAEUM

The oesophagus, which is continuous with the cibarial pump, is a short, narrow tube that extends posteriorly between the head ganglia through the cervix, and joins the cardia of the ventriculus in the anterior part of the thorax. Within the thorax anterior to the cardia is the evaginated crop duct coming off the ventral side of the oesophagus and extending caudad beneath the ventriculus into the abdomen. Here it enlarges into an oblong thin-walled sac. The crop is capable of considerable distension and occupies most of the anterior part of the abdominal cavity of flies which have fed on sweetened water. However, no blood was found in the crop of flies which had fed on turkeys. The cardiac valve (pl. 2, *B*) marks the junction of the fore and mid intestine.

MESENTERON

The mid intestine, or ventriculus, is a straight tube of varying diameter. The anterior part is narrow and tubelike and extends along the median line of the body to the abdomen where it expands over the crop, the degree of expansion depending on the amount of blood the fly has consumed. The mid intestine is marked at its anterior end by the cardiac valve and at the posterior end by the pyloric valve. The posterior portion of the mid intestine narrows slightly where it joins the hind intestine.

PROCTODAEUM

The hind intestine is marked anteriorly by the pyloric valve and posteriorly by the rectum. At the point of junction of the mid and the hind intestine four Malpighian tubules arise, one pair on each side of the intestine. They are of considerable length and follow an irregular course through the abdominal cavity.

The anterior part of the hind intestine is a slightly tapering tube which may or may not be curved, depending on the development of the ovaries. This is known as the distal intestine. The posterior part of the hind intestine forms a flask-shaped sac called the rectal pouch, which contains six rectal glands. The rectal glands are arranged in a circle around the opening of the distal intestine and are visible through the thin walls of the rectal pouch.

The rectum is a short tube which extends from the rectal pouch to the anus.

HISTOLOGY OF THE ALIMENTARY TRACT

MOUTH PARTS AND BITING APPARATUS

The mouth parts, being true appendages of the head, have the same structure as the body wall. The chitinous lining of the food channel is heavy and rigid. It is overlain by a very thin layer of epithelium; and bands of muscles extend from the body wall to the labrum-epipharynx and the labium-hypopharynx.

The walls of the basipharynx are heavy, chitinous structures overlain by a thin layer of epithelium. Muscle bands are attached to its anterior face.

SALIVARY GLANDS

The salivary glands are tubular and are composed of a single layer of cells whose bases rest on the basement membrane. The elongated secretory portion of each gland is composed of large cuboidal cells and the reservoir part is made up of small flattened cells (pl. 3, *D*). From the reservoir part of each gland a slender duct arises, which unites with that of the other gland to form the common salivary duct. A short distance from the point of junction, the duct expands to form the salivary syringe, whose walls are strengthened by riblike sclerotizations (pl. 2, *C*). The walls of the salivary duct are composed of a chitinous intima and a very thin layer of epithelium. No muscle layer was found on either the glands or the duct.

STOMODAEUM

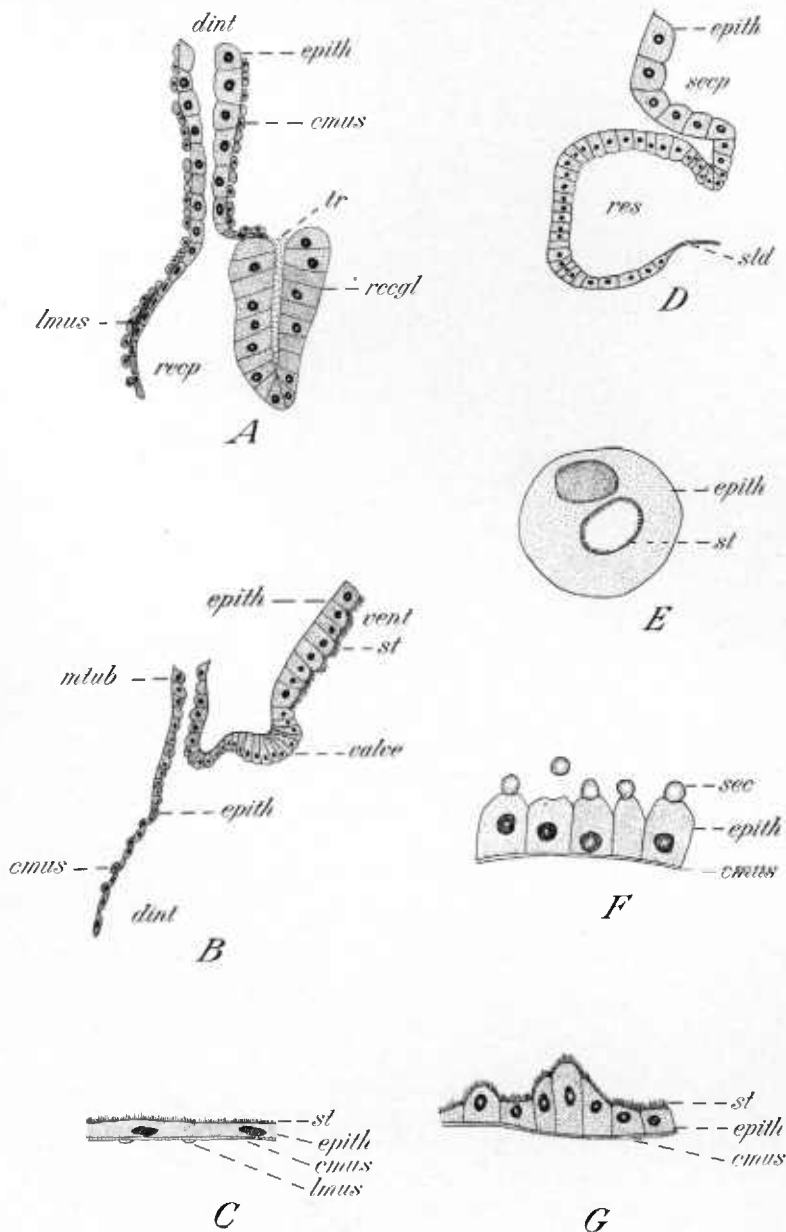
The oesophagus and its diverticulum, the crop, are true stomodeal structures and show a similar histological structure. The chitinous intima is so thin that it cannot be detected in most sections. Also, a thin layer of epithelium is found in all parts and is composed of flattened cells joined at their bases to a basement membrane. Covering the epithelium is a layer of circular muscle fibers. In the crop both the epithelial and the muscle layer are extremely thin.

The oesophagus extends well into the ventriculus and is represented by a single layer of epithelial cells. The inability to distinguish a chitinous intima makes the determination of the limits of the fore intestine difficult. It is also difficult to determine the ectodermal from the endodermal tissue in sections through the cardiac valve.

MESENTERON

The mid intestine, or ventriculus, differs from the fore and the hind intestine in histological structure. The inner and most conspicuous layer of the stomach is that of the epithelium, the bases of whose cells rest on the basement membrane (pl. 2, *D*). Following the basement membrane is a very thin layer of circular muscles and over these are scattered longitudinal muscles. The cells of the epithelium are columnar (pl. 3, *G*) and are sometimes thrown into irregular folds. The epithelium of the posterior part of the stomach is variable in thickness and, when the gut is distended with food, is only about one-third the thickness of the normal epithelium (pl. 3, *C*). The epithelial cells in all parts of the mid intestine show a striated inner margin.

The epithelium of the mid intestine functions in the secretion of digestive fluids. The secretion is merocrine inasmuch as the entire cell does not burst. Sections taken through the stomach of an unfed



Simulium nigroparvum. A, Longitudinal section through a portion of the distal intestine and one rectal gland; B, longitudinal section through pyloric region; C longitudinal section through the ventriculus of an engorged fly showing reduced epithelium; D, longitudinal section through salivary gland; E, cross section through Malpighian tubule; F, longitudinal section through ventriculus of an unfed fly; G, longitudinal section through ventriculus showing cuboid epithelium. *cmus*, Circular muscle; *dint*, distal intestine; *epith*, epithelium; *lmus*, longitudinal muscle; *mtub*, malpighian tubule; *recgl*, rectal gland; *recp*, rectal pouch; *res*, reservoir; *sec*, secretion; *secp*, secretory part; *sld*, salivary duct; *st*, striated margin of cell; *tr*, tracheal branch; *vent*, ventriculus.

fly show a very active secretion taking place (pl. 3, *F*). The inner end of the cells bud off and there is no rupturing of the cell wall. During the process of secretion the epithelial cells do not show the striated border.

PROCTODAEUM

The hind intestine is marked anteriorly by the pyloric valve. This valve is formed by a ring of epithelial cells at the end of the mid intestine. These cells, unlike those found in the stomach, have no striated border. The lip of the valve encircles the intestine just anterior to the opening of the Malpighian tubules (pl. 3, *B*). The cells of the Malpighian tubules are of the characteristic cuboidal shape and are continuous with the epithelium of the hind intestine. A short distance from the point of attachment, the cells of the Malpighian tubules are narrow and elongated with conspicuous nuclei. Their inner margins are distinctly striated (pl. 3, *E*).

The epithelium of the distal intestine consists of flattened cells, which are raised into folds in the posterior part. Covering the epithelium is a layer of circular muscles which forms a continuous layer at the posterior end. As in the fore intestine, the intima in the distal intestine is too thin to be readily demonstrated.

The walls of the rectal pouch are extremely thin and the epithelium is greatly reduced except where it forms the rectal glands. Both muscle layers are very thin and the rectal glands are readily visible through the walls of the rectal pouch. The rectal glands (pl. 3, *A*) are composed of large cells with prominent nuclei. The lumen of each gland is occupied by a tracheal branch. The chitinous intima is very thin and not easily demonstrated in the rectal pouch.

The posterior end of the rectal pouch narrows abruptly to form the rectum. Here both muscle layers as well as the epithelium are well developed and the chitinous intima lining the rectum can easily be detected.

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